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W. B. MILLER

DESIGN OF A REINFORCED CONCRETE WAREHOUSE

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DESIGN OF A REINFORCED CONCRETE WAREHOUSE

BY

WILLIAM BOYD MILLER

A Thesis Submitted for the Degree of

BACHELOR OF SCIENCE

Civil Engineering Course

UNIVERSITY OF WISCONSIN

1908

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Design of a Reinforced Concrete Warehouse

Preliminary Considerations

It is the purpose of this thesis to economically design a reinforced concrete warehouse for storing general merchandise to be located in the vicinity of Chicago, Illinois.

This warehouse is to be located on a lot having a frontage of 150 feet on a street and 200 feet deep and so situated that side tracks could be run into the building at an elevation about 20 feet below the street.

It was thought best to make the building U shaped and to run two tracks into the center of the U each able to hold three cars. A floor is to be built over the tracks, for wagons to drive on, having an entrance from the street through the base of the U. This floor is to be about the same level as the street and to be covered by a roof of steel roof trusses and tile roofing with skylights of glass tile

(See Drawings No. 1, 2, 20 & 21)

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General Plan.

Two different designs of column spacing and beam arrangement were made together with a rough estimate to determine the relative costs. In making this estimate, that portion of one floor of the building forming one leg of the U, and the driving floor were roughly designed for each case and quantities of steel and concrete computed. These two designs were called Estimate Design No. 1 and Estimate Design No. 2.

Having determined which design was more economical, a final design was made in much the same manner as the preliminary designs but in more detail.

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-Specifications for Preliminary Designs.-

No drawings were made for the preliminary designs. The girders were figured as simple beams in each case, and while this is not correct, it was considered sufficiently accurate for an estimate.

As the building was designed for storing general merchandise, the loading on the floors was assumed to be 250 pounds per square foot and that on the driving floor, 350 pounds.

The unit working stress of steel in tension was taken as 12000 pounds per square inch. The unit working stress of concrete in compression was taken as 600 pounds per square inch in beams and 500 pounds per square inch in columns. The size and weight of each member was first figured and then refigured with the weight of the member added to the loading, the weight of the reinforced concrete being taken as 150 pounds per cubic foot.

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NOTATION

L denotes length of span in feet

W denotes load in lbs. per lin. ft. of beam

f_s denotes unit fibre stress in steel

f_c denotes unit fibre stress in concrete at its compressive face.

E_s denotes modulus of elasticity of the steel

E_c denotes modulus of concrete in compression

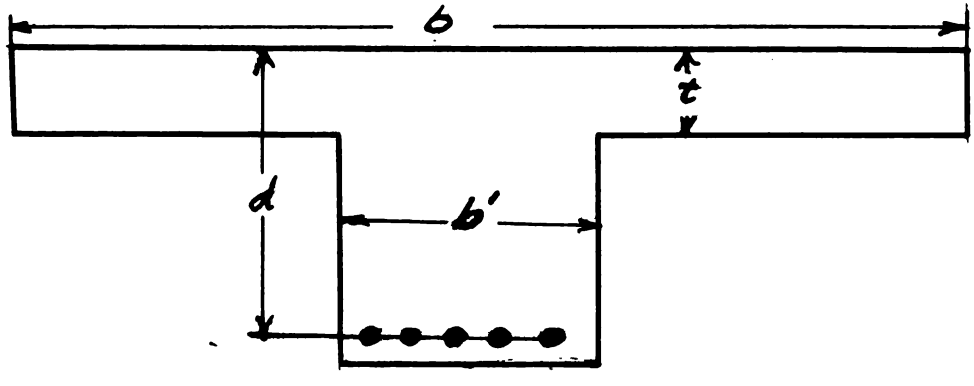
n denotes ratio E_s divided by E_c

b denotes breadth of a rectangular beam

d denotes distance from the compressive face to the plane of the steel.

A denotes area of cross section of steel

p denotes steel ratio A divided by bd



In T Beams

b denotes width of flange

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d denotes effective depth of beam

b' denotes width of web

t denotes thickness of flange

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PRELIMINARY DESIGN NO. 1.

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FLOOR SLAB.

$L = 7.5'$ $\quad W = 250\#$

$M = \frac{1}{8} \times 250 \times (7.5)^2 \times 12 = 21{,}020''\#s$

$$\frac{M}{bd^2} = 109 = \frac{21{,}020}{12 \times d^2}$$

$$d = \sqrt{\frac{21{,}020}{12 \times 109}} = 4.1''$$

Wt of lin. ft. of slab $= \frac{12 \times 4.1}{144} \times 150 = 50.2\#$

$W = 250 + 50 = 300\#$

$M = \frac{1}{8} \times 300 \times (7.5)^2 \times 12 = 25{,}250''\#s$

$$\frac{M}{bd^2} = 109 = \frac{25{,}250}{12 \times d^2}$$

$$d = \sqrt{\frac{25{,}250}{12 \times 109}} = 4.4'' = 4\tfrac{3}{8}''$$

Area of steel = .0107 x 4.4 x 12 = .565 sq. inches.

CROSS BEAMS.

$$d = t\left(\frac{f_s}{nf_c} + 1\right) \qquad d = 4.375\left(\frac{12000}{15 \times 600} + 1\right) = 10.2''$$

$W = 300 \times 7.5 = 2250\#$

$M = \frac{1}{8} \times 2250 \times 297.5 \times 12 = 1{,}002{,}500''\#s$

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$$A = \frac{M}{(d - \frac{1}{2}t)f_s} = \frac{1,002,500}{(20 - 2,187)12000} = \frac{1,002,500}{213,800} = 4.7$$

sq. inches.

$$C = \frac{M}{(d - \frac{1}{2}t)} = \frac{1,002,500}{17.81} = 56,300\#$$

$$f_c = \frac{2C}{bt} \quad b = \frac{2C}{tf_c} = \frac{2 \times 56,300}{4,375 \times 600} = \frac{112,600}{2,620} = 43"$$

$b = 6"$

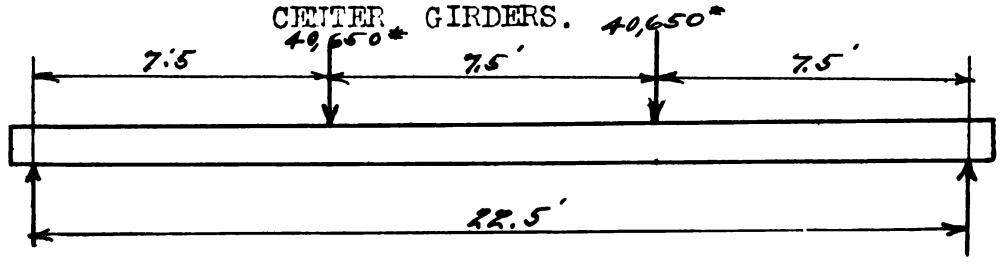
Wt per ft. of beam $\frac{6 \times 15.63}{144} \times 150 = 97.5\#$

$W = 2250 + 98 = 2348\#$

$M = \frac{1}{8} \times 2348 \times 297.5 \times 12 = 1,048,500"\#s$

$$A = \frac{1,048,500}{(20 - 2.19)12000} = \frac{1,048,500}{213,800} = 4.81 \text{ sq. inches}$$

CENTER GIRDERS.



$M = (40,650 \times 11.25 - 40,650 \times 3.75)12 = 3,662,000"\#s$

$$\frac{M}{bd^2} = 109 = \frac{3,662,000}{24 \times d^2}$$

$$d = \sqrt{\frac{3,662,000}{24 \times 109}} = 37.4"$$

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Wt per ft. of beam = $\frac{37.4 \times 24}{144} \times 150 = 935\#$

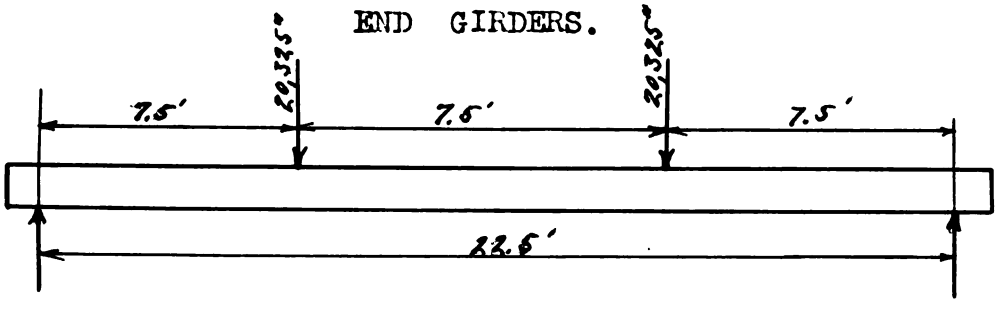
M = (51,160 x 11.25 - (40,650 x 3.75 + 935 x 11.25 x 5.625)) 12 = 4,360,000#"s

$\frac{m}{bd^2} = 109 = \frac{4,360,000}{24 \times d^2}$

$d = \sqrt{\frac{4,360,000}{24 \times 109}} = 40.85"$

% of steel = $\frac{24 \times 40.85}{} \times .01 = 9.8$ sq. inches.

END GIRDERS.



M = (20,325 x 11.25 - 20,325 x 3.75) 12 = 1,809,000"#s

$\frac{M}{bd^2} = 109 = \frac{1,809,000}{16 \times d^2}$

$d = \sqrt{\frac{1,809,000}{16 \times 109}} = 32.19$

Wt. per ft. of beam = $\frac{16 \times 32.19}{144} \times 150 = 535.5\#$

M = (26,350 x 11.25 - (20,325 x 3.75 + 535.5 x 11.25 x 5.625)) 12 = 2,231,500"#s.

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END GIRDERS.

$$\frac{M}{bd^2} = 109 = \frac{2,231,500}{16 \times d^2}$$

$$d = \sqrt{\frac{2,231,500}{16 \times 109}} = 35.8"$$

% of steel = 35.8 x 16 x .01 = 5.72 sq. inches.

CENTER COLUMNS.

Load on column due to one floor = 142,970#

$$A = \frac{P'}{f_c\ (1 + (n - 1)P)}$$

$$A = \frac{142,970}{500(1 + (15 - 1).01} = 251 \text{ sq. inches.}$$

Wt of 10' column = $\frac{251}{144}$ x 10 x 150 = 2615#

P' = 142,970 + 2615 = 145,585

$$A = \frac{145,585}{500(1 + (n - 1)P)} = 255.7 \text{ sq. inches.}$$

SIDE COLUMNS.

Load on column due to one floor = 73,025#

$$A = \frac{73,025}{500(1 + (n - 1)P)} = 128.1 \text{ sq. inches.}$$

Wt. of 10' column = $\frac{128.1}{144}$ x 10 x 150 = 1335#

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$$A = \frac{74,350}{500(1+(n-1)P} = 130.2 \text{ sq. inches.}$$

Area of steel = 1.3 sq. inches.

CORNER COLUMNS.

Load on column due to one floor = 46,675#

$$A = \frac{46,675}{500\ (1+(n-1).01} = 82 \text{ sq. inches.}$$

$$\text{Wt of 10' column} = \frac{82}{144} \times 10 \times 1.50 = 854.5\#$$

P' = 46,675 + 853 = 47,530

$$A = \frac{47,530}{500(1+(n-1).01} = 83.5 \text{ sq. inches.}$$

Area of steel = .84 sq. inches.

No.	Member	Cu. Ft. per Member	Cu.Ft. Con.
16	Slabs	$\frac{4375 \times 12}{144} \times 17.25 \times 22.5 =$ 141.5 ft^3	2264
16	Cross Beams	$\frac{15.62 \times 8}{144} \times 17.25 = 15\ ft^3$	840
16	Center Girders	$\frac{4085 \times 24}{144} \times 22.5 = 153\ ft^3$	2450
2	End Girders	$\frac{35.8 \times 16}{144} \times 22.5 = 89.5\ ft^3$	179

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8 Center Columns	$\frac{255.7}{144} \times 10 = 17.75$	142
17 Side Columns	$\frac{130.2}{144} \times 10 = 9.05$	154
2 Corner Columns	$\frac{83.5}{144} \times 10 = 5.8$	12
		6041

$\frac{6041}{27} = 224$ cu. yds.

No.	Member	Cu. Ft. per Member	Lbs. Steel
16	Slabs	$\frac{.565 \times 22.5}{144} \times 17.25 = 1.52\ ft^3$	11900
56	Cross Beams	$\frac{4.81}{144} \times 17.25 = .575\ ft^3$	15800
16	Center Girders	$\frac{9.8}{144} \times 22.5 = 1.53\ ft^3$	12000
2	End Girders	$\frac{5.72}{144} \times 22.5 = .895\ ft^3$	875
17	Side Columns	$\frac{1.30}{144} \times 10 = .093\ ft^3$	774
2	Corner Columns	$\frac{.84}{144} \times 10 = .0584\ ft^3$	57
8	Center Columns	$\frac{2.56}{144} \times 10 = .178\ ft^3$	696
			42,102#

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DRIVEWAY FLOOR.

Loading = 350# per square foot.

SLABS.

$$M = 350 \times \frac{(7.25)^2 \times 12}{10} = 22{,}190''\#s$$

$$\frac{M}{bd^2} = 109 = \frac{22{,}190}{12 \times d^2}$$

$$d = \sqrt{\frac{22{,}190}{12 \times 109}} = 4.115''$$

Wt. of one lin. ft. of Slab = $\frac{4.115 \times 12}{144} \times 150 = 51.5\#s$

$$W = 350 + 51.5 = 401.5$$

$$M = \frac{401.5 \times (7.25)^2 \times 12}{10} = 25{,}400''\#s$$

$$\frac{M}{bd^2} = 109 = \frac{25{,}400}{12 \times d^2}$$

$$d = \sqrt{\frac{25{,}400}{12 \times 109}} = 4.41''$$

Area of steel = 4.41 x 12 x .01 = .53 sq. inches.

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CROSS BEAMS.

$W = 350 \times 7.25 = 2539\#$

$$M = \frac{2539 \times (17.25)^2 \times 12}{10} = 903{,}000''\#s$$

$$C = \frac{M}{(d - \frac{1}{2}t)} = \frac{903{,}000}{(20 - 2.2)} = 50{,}800$$

$$b = \frac{2C}{tf_c} = \frac{101{,}600}{4.41 \times 600} = \frac{101{,}600}{2{,}647} = 38.4''$$

$b = 8''$

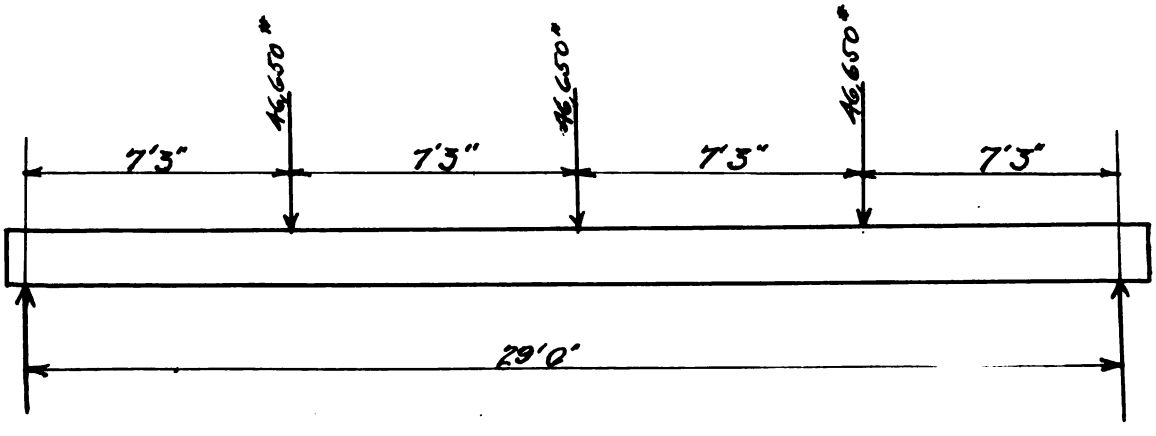
$$\text{Wt. of one lin. ft. of Beam} = \frac{20 \times 8}{144} \times 150 = 166.5$$

$W = 2539 + 167 = 2706$

$$M = \frac{2706 \times (17.75)^2 \times 12}{10} = 964{,}000$$

$$A = \frac{M}{(d - \frac{1}{2}t)\, f_s} = \frac{964{,}000}{(20 - 2.2)12000} = \frac{964{,}000}{213{,}850} = 4.51 \text{ sq.in.}$$

CENTER GIRDERS.



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$M = (69,980 \times 14.5 - 46,650 \times 7.25) \times 12 = 8,110,000$

$$\frac{M}{bd^2} = 109 = \frac{8,110,000}{36 \times d^2}$$

$$d = \sqrt{\frac{8,110,000}{36 \times 109}} = 45.5''$$

Wt. of one lin. ft. of beam = $\frac{36 \times 45.5}{144} \times 150 = 1708\#$

$M = (94,230 \times 14.5 - (46,650 \times 7.25 + 1708 \times 14.5 \times$

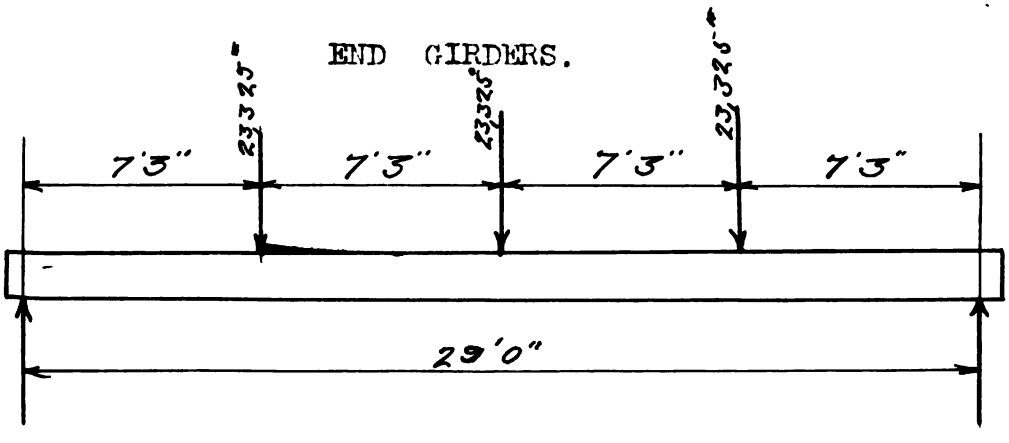
$7.25))12 = 10,197,000''\#s$

$$\frac{M}{bd^2} = 109 = \frac{10,197,000}{36 \times d^2}$$

$$d = \sqrt{\frac{10,197,000}{36 \times 109}} = 51''$$

Area of steel = 51 x 36 x .01 = 18.35 sq. inches.

END GIRDERS.



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$M = (34,987 \times 14.5 - 23,325 \times 7.25)12 = 4,060,000$"#s

$$\frac{M}{bd^2} = 109 = \frac{44,060,000}{24 \times d^2}$$

$$d = \sqrt{\frac{41,060,000}{109 \times 24}} \times 39.4"$$

Wt. of one lin. ft. of beam $= \frac{24 \times 39.4}{144} \times 150 = 985$#

$M = (49,282 \times 14.5 - (23,325 \times 7.25 + 985 \times 14.5 \times$

$7.25))12 = 5,310,000$"#s

$$\frac{M}{bd^2} = 109 = \frac{5,310,000}{24 \times d^2}$$

$$d = \sqrt{\frac{5,310,000}{24 \times 109}} = 45.06"$$

Area of steel $= 24 \times 45.06 \times .01 = 10.81$ sq. inches.

CONCRETE.

No.	Members.	Cu. Ft. per Member	Cu.Ft
16	Slabs	$\frac{4.40 \times 12 \times 17.25}{144} \times 29 = 183.7$	2940
56	Cross Beams	$\frac{17.8 \times 8}{144} \times 17.25 = 17.05$	954
14	Center Girders	$\frac{51 \times 36}{144} \times 29 = 370$	5180

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CONCRETE (continued)

No.	Members	Cu. Ft. per Member	Cu. Ft.
2	End Girders	$\frac{24 \times 45.06}{144} \times 29 = 218$	436
			9,510

$\frac{9,510}{27} = 353$ Cu. Yds.

STEEL.

			Lbs.
16	Slabs	$\frac{.53 \times 17.25}{144} \times 29 = 1.24$	14,400
56	Cross Beams	$\frac{4.51}{144} \times 17.25 = 0.54$	14,800
14	Center Girders	$\frac{18.35}{144} \times 29 = 3,695$	25,300
2	End Girders	$\frac{10.81}{144} \times 29 = 2.18$	2,135
			56,635#

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PRELIMINARY DESIGN NO. 2.

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FLOOR SLAB.

L = 7'8" W = 250

$$M = \frac{7.66^2 \times 250 \times 12}{8} = 22,100$$

P = .0107

$$\frac{M}{bd^2} = 109 = \frac{22,100}{12 \times d^2}$$

$$d^2 = \frac{22,100}{12 \times 109} = 16.9$$

d = 4.11 = 4⅛"

$$\text{Wt. of Lin. ft. of Slab} = \frac{4.11 \times 12}{144} \times 1 \times 150 = 51.4\#$$

W = 250 + 51.4 = 301.4#

$$M = \frac{301 \times 7.66^2 \times 12}{8} = 26,580$$

P = .0107

$$\frac{M}{bd^2} = 109 = \frac{26,580}{12 \times d^2}$$

$$d^2 = \frac{26,580}{12 \times 109} = 20.3$$

d = 4.5"

Area of steel = .0107 x 4.5 x 12 = .578 sq. inches.

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CROSS BEAMS.

$W = 300 \times 7.66 = 2,300$

$M = \frac{1}{8} \times 2,300 \times 225 \times 12 = 775,500$"#s

$$C = \frac{M}{(d - \frac{1}{2}t)} = \frac{775,500}{(16 - 2.25)} = 56,400\#$$

$$b = \frac{2C}{tf_c} = \frac{112,800}{5 \times 600} = 41.8"$$

$$A = \frac{M}{(d - \frac{1}{2}t)f_s} = \frac{775,500}{(16 - 2.25)12000} = 4.7 \text{ sq. inches.}$$

$b' = 8"$

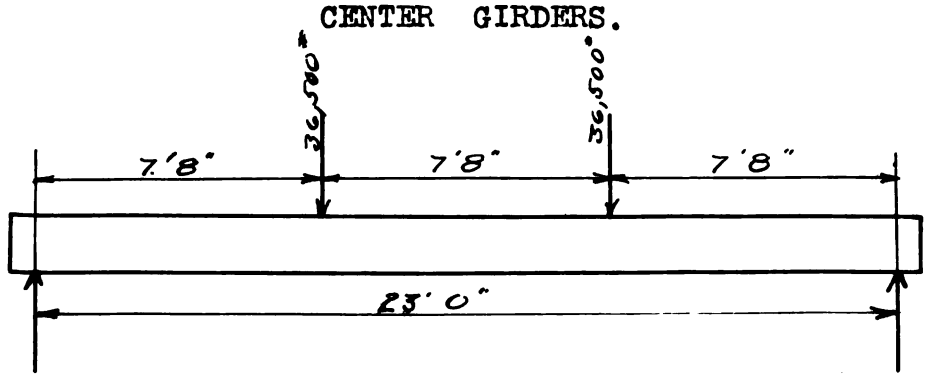
$$\text{Wt of lin. ft. of beam} = \frac{8 \times 16}{144} \times 150 = 133\#$$

$W = 2,300 + 133 = 2,433\#$

$M = \frac{1}{8} \times 2,433 \times 225 \times 12 = 820,000$"#s

$$A = \frac{M}{(d - \frac{1}{2}t)f_s} = \frac{820,000}{(16 - 2.25)12000} = 4.975 \text{ sq. in}$$

CENTER GIRDERS.



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$M = (36{,}500 \times 11.5 - 36{,}500 \times 3.83)12 = 3{,}230{,}000$"#s

$$\frac{M}{bd^2} = 109 = \frac{3{,}230{,}000}{24 \times d^2}$$

$$d = \sqrt{\frac{3{,}230{,}000}{24 \times 109}} = 35.15"$$

$$\text{Wt per ft . of beam} = \frac{24 \times 35.15}{144} \times 150 = 878\#$$

$M = (46{,}600 \times 11.5 - (36{,}500 \times 3.83 + 878 \times 11.5 \times 5.75)$

$\times 12$

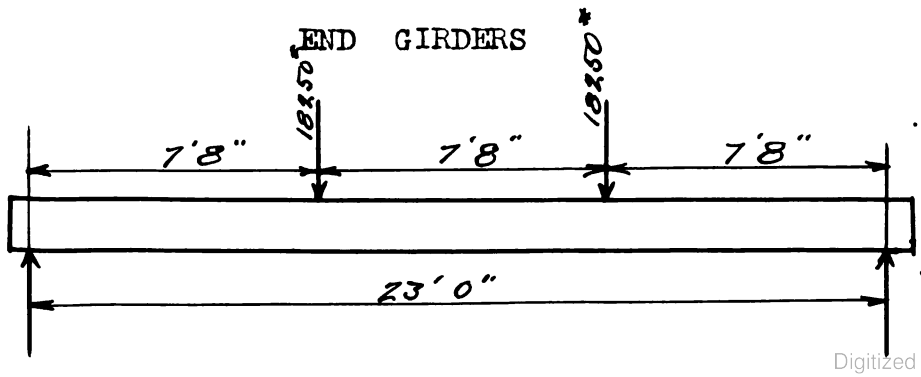
$M = (536{,}000 - (139{,}800 + 58{,}050))12 = 4{,}058{,}000$

$$\frac{M}{bd^2} = 109 = \frac{4{,}058{,}000}{24 \times d^2}$$

$$d = \sqrt{\frac{4{,}058{,}000}{24 \times 109}} = 39.4"$$

% of steel = 39.4 x 24 x .01 = 9.45 sq. inches.

END GIRDERS



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$M = (18,250 \times 11.5 - 18,250 \times 3.88)12 = 1,561,500$"#s

$$\frac{M}{bd^2} = 109 = \frac{1,561,500}{16 \times d^2}$$

$$D = \sqrt{\frac{1,561,500}{16 \times 109}} = 29.9"$$

Wt per ft. of Beam = $\frac{16 \times 29.9}{144} \times 150 = 498.5$#

$M = (23,980 \times 11.5 - (18,250 \times 3.88 + 498.5 \times 11.5 \times 5.75))$

$\times 12 = 2,060,000$"#s

$$\frac{M}{bd^2} = 109 = \frac{2,060,000}{16 \times d^2}$$

$$d = \sqrt{\frac{2,060,000}{16 \times 109}} = 34.4"$$

Area of slab = 34.4 x 16 x .01 = 5.5 sq. inches.

CENTER COLUMNS.

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Wt on column due to one floor = 46,600 x 2 + 36,500 = 129,700#

$$A = \frac{129,700}{500(1+(15 - 1).01} = 227.7 \text{ sq. inches.}$$

$$\text{Wt of 10' column} = \frac{227.7}{144} \times 150 \times 10 = 2370\#$$

P' = 129,700 + 2,370 = 132,070#

$$A = \frac{132,070}{500(1 + (15 - 1).1)} = 232 \text{ sq. inches.}$$

Area of steel = 2.32 sq. inches.

SIDE COLUMNS.

Wt on column due to one floor = 23,980 x 2 + 18,250 = 66,210#

$$A = \frac{66,210}{500(1+(15 - 1).01} = 116.1 \text{ sq. inches.}$$

$$\text{Wt of 10' column} = \frac{116.1}{144} \times 150 \times 10 = 1210\#$$

P = 66,210 + 1210 = 67,420#

$$A = \frac{67,420}{500(1+(15 - 1).01)} = 118.1 \text{ sq. inches.}$$

Area of steel = 1.18 sq. inches.

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CORNER COLUMNS.

Wt of column due to one floor = 23980 + 18,250 = 42,230#

$$A = \frac{42,230}{500(1 + (15 - 1).01)} = 74.1 \text{ sq. inches.}$$

$$\text{Wt of 10' column} = \frac{74.1}{144} \times 10 \times 150 = 772\#$$

P = 42,230 + 772 = 43,002#

$$A = \frac{43,002}{500(1 + (15 - 1).01)} = 75.5 \text{ sq. inches.}$$

Area of steel = .76 sq. inches.

No.	Member	Cu. Ft. per Member	Cu. Ft. Con
54	Slabs	$\frac{4.5 \times 12}{144} \times 15 \times 7.66 = 43.1 ft^3$	2326
57	Cross Beams	$\frac{11.5 \times 8}{144} \times 15 = 9.56\ ft^3$	545
12	Center Columns	$\frac{232}{144} \times 10 = 16.11\ ft^3$	193
14	Side Columns	$\frac{118.1}{144} \times 10 = 8.2 ft^3$	115
2	Corner Columns	$\frac{75.5}{144} \times 10 = 5.25\ ft^3$	11
12	Center Girders	$\frac{39.4 \times 24}{144} \times 23 = 151\ ft^3$	1810
12	End Girders	$\frac{34.4 \times 16}{144} \times 23 = 87.8\ ft^3$	1053
			6053

$\frac{6053}{27}$ = [illegible]

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No.	Member	Cu. Ft. Steel per Member	Lbs. steel
54	Slabs	$\frac{0.578 \times 15}{144} \times 23 = 1.383\ ft^3$	36500
57	Cross Beams	$\frac{4.975}{144} \times 15 = .518\ ft^3$	1450
12	Center Girders	$\frac{9.45}{144} \times 23 = 1.51\ ft^3$	8880
12	End Girders	$\frac{5.5}{144} \times 23 = 0.878\ ft^3$	5160
12	Center Columns	$\frac{2.32}{144} \times 10 = .161\ ft^3$	948
14	Side Columns	$\frac{1.18}{144} \times 10 = .082\ ft^3$	563
2	Corner Columns	$\frac{.76}{144} \times 10 = .0528\ ft^3$	49
			53,550

DRIVEWAY FLOOR.

Loading = 350# per sq. ft.

SLABS.

Same as in Case 1.

CROSS BEAMS.

$W = 350 \times 7.25 = 2539\#$

$M = \frac{2539 \times (23)^2 \times 12}{10} = 1,609,500''\#s$

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$$C = \frac{M}{(d - \frac{1}{2}t)} = \frac{1,609,500}{36 - 2.2} = 47,600$$

$$b = \frac{2C}{tf_c} = \frac{47,600 \times 2}{4.41 \times 600} = \frac{95,100}{2,647} = 35.95''$$

$$b = 15''$$

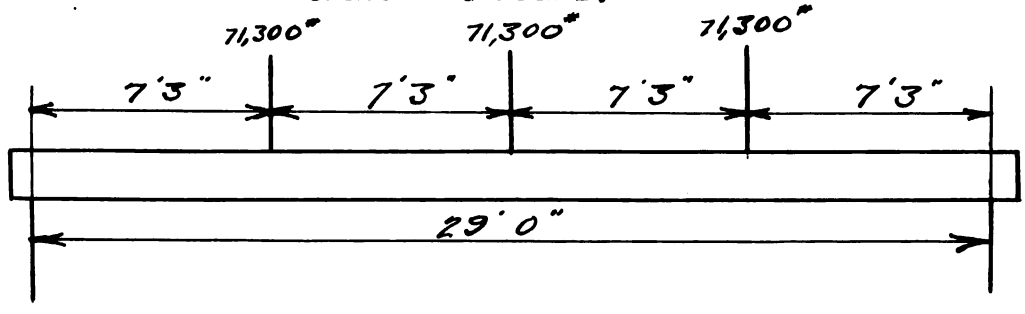
Wt of one lin. ft. of beam $= \frac{15 \times 3}{144} \times 150 = 561\#$

$$W = 2539 + 561 = 3100\#$$

$$M = \frac{3100 \times (23)^2 \times 12}{10} = 1,975,000''\#s$$

$$A = \frac{M}{(d - \frac{1}{2}t)f_s} = \frac{1,975,000}{(36 - 22)12000} = 4.865 \text{ sq. inches}$$

CENTER GIRDERS.



$$M = (106,950 \times 14.5 - 71,300 \times 7.25)12 = 12,410,000''\#$$

$$\frac{M}{bd^2} = 109 = \frac{12,410,000}{36 \times d^2}$$

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$$d = \sqrt{\frac{12,410,000}{36 \times 109}} = 56.4''$$

Wt of one lin. ft. of Beam = $\frac{36 \times 56.4}{144} \times 150 = 2112\#$

$M = (137,574 \times 14.5 - (71,300 \times 7.25 + 2112 \times 14.5$

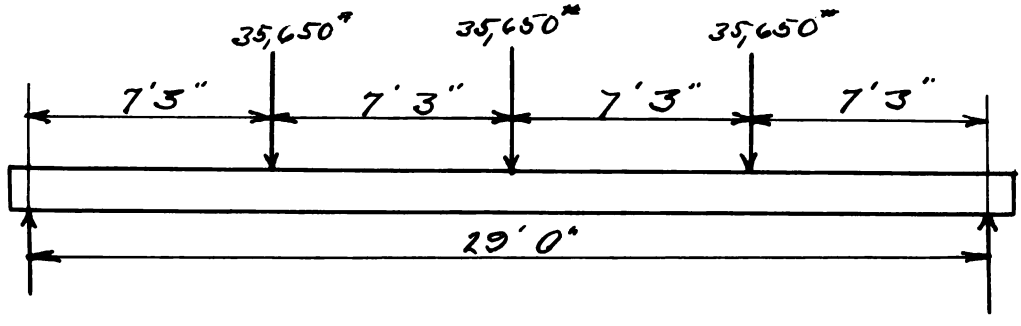
$\times 7.25))12 = 15,015,000''\#s$

$$\frac{M}{bd^2} = 109 = \frac{15,015,000}{36 \times d^2}$$

$$d = \sqrt{\frac{15,015,000}{36 \times 109}} = 61.9''$$

Area of steel = 36 x 61.9 x .01 = 22.25 sq. inches.

END GIRDERS.



$M = (53,475 \times 14.5 - 35,650 \times 7.25)12 = 6,075,000''\#s$

$$\frac{M}{bd^2} = 109 = \frac{6,075,000}{30 \times d^2}$$

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$$d = \sqrt{\frac{6,075,000}{30 \times 109}} = 43.1"$$

Wt per lin. ft. of Beam $= \frac{30 \times 43.1}{144} \times 150 = 1349\#$

$M = (73,000 \times 14.5 - (35,650 \times 7.25 + 1349 \times 14.5 \times 7.25))$

$\times 12 = 7,900,000$"#s

$$\frac{M}{bd^2} = 109 = \frac{7,900,000}{30 \times d^2}$$

$$d = \sqrt{\frac{7,900,000}{30 \times 109}} = 49.2"$$

Area of steel = 30 x 49.2 x .01 = 14.75 sq. inches.

DRIVING FLOOR.

No.	Member	Cu. Ft. per Member	Cu. Ft.
12	Slabs	$\frac{4.41 \times 12 \times 23}{144} \times 29 = 245.2$	2940
42	Cross Beams	$\frac{15 \times 33.8}{144} \times 23 = 81$	3400
10	Center Girders	$\frac{36 \times 61.9}{144} \times 29 = 448.5$	4485
2	End Girders	$\frac{30 \times 49.2}{144} \times 29 = 297.7$	595
			11420

$\frac{11420}{27} = 424$ cu. yds.

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STEEL.

No.	Member	Cu. Ft. per Member	Lbs. Ste
12	Slabs	$\frac{0.53 \times 23}{144} \times 29 = 2.45$	14400
42	Cross Beams	$\frac{4,865}{144} \times 23 = 1.14$	23420
10	Center Girders	$\frac{22.25}{144} \times 29 = 4.48$	21970
2	End Girders	$\frac{14.75}{144} \times 29 = 3.625$	3555
			63,345

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FINAL DESIGN.

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-Final Considerations.-

Very little difference was found between the quantities of steel and concrete required in the two designs. Design No. 1 was selected because it gave a better spacing for the roof trusses. It was desirable to have the roof trusses bear on columns and No. 1 gave the trusses a spacing of 17 ft. 3 ins., while No. 2, a spacing of 23 ft. 0 ins., which is too large.

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Specifications for Final Design.

The concrete used was a 1-2-4 mixture with an ultimate compressive strength of 2400 lbs. per sq. in., giving a working stress of 600 lbs. in beams and 500 lbs. in columns. The steel selected had an elastic limit of 36,000 lbs. per sq. in., giving a working stress of 12000 lbs. per sq. in.

In order to systematise and reference the computations, the building was divided into five sections numbered A, B, C, D, & E, as shown by one of the accompanying drawings. (See Drawing No. 1)

It was decided to make the walls of brick, eight inches thick, and have them rest on top of the side beams and girders. The cross beams in the walls as computed were the same as the center beams and, although the girders as computed were a little smaller, it was thought best to make them the same size as the center girders.

The roof was given a slope on one inch to one foot and was covered with four thicknesses of felt and a coat of tar and gravel.

The pressure allowed on the foundation was

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two tons per square foot and as no footings were allowed to project outside of the building line, it was necessary to design cantilever girders.

Plain round bars were used for reinforcement as the merits of the patent reinforcing are somewhat doubtful and the adhesion between concrete and plain rods is known more exactly.

About one half of the longitudinal reinforcement in the beam and girders was turned up near the quarter points but was not counted on as web reinforcement Sufficient stirrups were put in to supply all the web reinforcement needed.

In the girders where the negative moment over the supports is very great the stirrups were reversed so that they would be better anchored in the top of the beam which is the tension side at these points. It was also necessary to have the girders of greater depth over the supports. This deeper part was connected to the other part by a curve of ten foot radius, tangent to the shallow part of the beam and intersecting the deeper part at the side of the columns.

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In designing the columns all the required steel was placed longitudinally and was held in place by one eighth inch wire bracing placed every six inches. No columns smaller than twelve inches were used and all the fourth floor columns were of this size. Detail drawings were made of all the members on a scale of three eighths inch to one foot and one inch to one foot and also two drawings showing cross sections of the building on a scale of one eighth inch to one foot

In detailing the members, fillets were put in the corners and the sharp edges were cut off so as to avoid sharp reentrant angles into which it is hard to get the concrete to flow.

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Design of Slabs, Beams, and Girders.

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SECTION A. (See Drawing No. 3)

FLOOR SLAB.

$Z = 7.5'$ $W = 250\#$

$f_c = 600\#/\text{sq. inch}$ $f_s = 12000\#/\text{sq. inch}$

$M = 1/10 \times 250 \times (7.5)^2 \times 12 = 16{,}800''\#s$

$$\frac{M}{bd^2} = 109 = \frac{16{,}800}{12 \times d^2}$$

$$d = \sqrt{\frac{16{,}800}{12 \times 109}} = 3.59''$$

Wt of lin. ft. of Slab $= \frac{12 \times 3.59}{144} \times 150 = 44.9\#$

$W = 250 + 45 = 295\#$

$M = 1/10 \times 295 \times (7.5)^2 \times 12 = 19{,}870''\#s$

$$\frac{M}{bd^2} = 109 = \frac{19{,}870}{12 \times d^2}$$

$$d = \sqrt{\frac{19{,}870}{12 \times 109}} = 3.9'' \text{ Use } 4''$$

Area of steel $= .0107 \times 3.9 \times 12 = .5$ sq. inches.

Over Supports

$M = 1/12 \times 295 \times (7.5)^2 \times 12 = 16{,}550''\#s$

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$$\frac{M}{bd^2} = 109 = \frac{16,550}{12 \times d^2}$$

$$d = \sqrt{\frac{16,550}{12 \times 109}} = 3.56''$$

Area of steel = 3.56 x 12 x .0107 = .457 sq. inches.

CROSS BEAMS.

$$d = t(\frac{f_s}{nf_c} + 1) \quad d = 3.9(\frac{12000}{15 \times 600} + 1) = 9.1''$$

$$W = 295 \times 7.5 = 2210\#$$

$$M = 1/10 \times 2,210 \times (17.25)^2 \times 12 = 788,000''\#s$$

$$C = \frac{M}{(d - \frac{1}{2}t)} = \frac{788,000}{2205} = 35,700\#$$

$$b = \frac{2C}{tf_c} = \frac{2 \times 35700}{3.9 \times 600} = 30.5''$$

$$b' = 12''$$

$$\text{Wt per ft. of Beam} = \frac{12 \times 20}{144} \times 150 = 167\#$$

$$W = 2210 + 167 = 2377\#$$

$$M = 1/10 \times 2377 \times (17.25)^2 \times 12 = 849,000''\#s$$

$$A = \frac{M}{(d - \frac{1}{2}t)f_s} = \frac{849000}{(24 - 1.95)12000} = 3.2''$$

Over Supports.

$$M = 1/12 \times 2377 \times (17.25)^2 \times 12 = 706000''\#s$$

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$$\frac{M}{bd^2} = 109 = \frac{706000}{b \times (24)^2}$$

$$b = \frac{706000}{109 \times 576} = 12''$$

Area of steel = .01 x 12 x 24 = 2.88 sq. inches.

$$\text{End Shear} = \frac{2377 \times 17.25}{2} = 20{,}440\#$$

Shear carried by concrete = 12 x 24 x 30 = 8,640

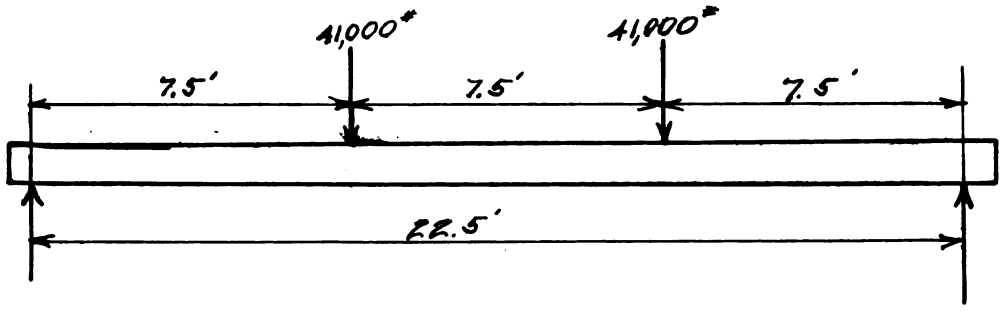
Shear to be carried by steel = 20440 - 8,640 = 11,800#

$$\text{Area of steel} = \frac{11800}{12000} = .984 \text{ sq. inches.}$$

$$\text{Area of stirrup} = \frac{.984}{2} = .49$$

$$\text{Average shearing stress} = \frac{20{,}440}{12 \times 24} = 71\# / \text{sq. inch}$$

CENTER GIRDERS.



$$M = \frac{41{,}000 \times 22.5 \times 12}{9} = 1{,}230{,}000$$

$$\frac{M}{bd^2} = 109 = \frac{1{,}230{,}000}{20 \times d^2}$$

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$$d = \sqrt{\frac{1,230,000}{20 \times 109}} = 23.8"$$

Negative Moment.

$$M = \frac{2 \times 41000 \times 22.5 \times 12}{9} = 2,460,000"\#s$$

$$\frac{M}{bd2} = 109 = \frac{2,460,000}{2o \times d^2}$$

$$d = \sqrt{\frac{2,460,000}{20 \times 109}} = 33.6"$$

Wt per ft. of Beam = $\frac{33.6 \times 20}{144} \times 150 = 700\#$

Pos. D.L. Moment = $\frac{700 \times (22.5)^2 \times 12}{10} = 425,000"\#s$

Negative D.L. Moment = $\frac{700 \times (22.5)^2 \times 12}{12} = 354000"\#s$

Total Positive Moment = 1,230,000 + 425,000 = 1,655,000"#s

$$\frac{M}{bd^2} = 109 = \frac{1,655,000}{70 \times d^2}$$

$$d = \sqrt{\frac{1,655,000}{20 \times 109}} = 27.8"$$

Area of steel = 27.8 x 20 x .0107 = 5.95 sq. inches.

Total Negative Moment = 2,460,000 + 354,000 = 2814000 "#s

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$$\frac{M}{bd^2} = 109 \quad \frac{2,814,000}{20 \times d^2}$$

$$d = \sqrt{\frac{2,814,000}{20 \times 109}} = 35.9''$$

Area of steel = 35.9 x 20 x .0107 = 7.68 sq. inches.

$$\text{End Shear} = 41,000 + \frac{700 \times 22.5}{2} = 48,860$$

Shear carried by concrete = 30 x 20 x 30 = 18,000

$$\text{Necessary web reinforcement} = \frac{30860}{12000} = 2.68 \text{ sq. inches}$$

$$\text{Area of stirrup } \frac{2.68}{2} = 1.34 \text{ sq. inches.}$$

Average shearing stress at point of max. moment and

$$\text{max. shear} = \frac{48860}{30 \times 20} = 83\#\ 1 \text{ sq. inch.}$$

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SECTION B. (See drawing No. 4)

FLOOR SLAB.

Same as in Section A.

d = 3.9" Use 4"

Area of steel = .457 sq. inches.

CROSS BEAMS.

$d = t(\frac{f_s}{nf_c} + 1)$ $d = 4(\frac{12000}{15 \times 600} + 1) = 9.35"$

W = 295 x 7.5 = 2210#

$M = 1/10 \times 2,210 \times (15)^2 \times 12 = 596,000"\#s$

$C = \frac{M}{(d - \frac{1}{2}t)} = \frac{596,000}{(22 - \frac{1}{2}\ 4)} = 29,800\#$

$b = \frac{2C}{tf_c} = \frac{2 \times 29,800}{4 \times 600} = 24.85"$

b = 12"

Wt per ft. of Beam = $\frac{12 \times 22}{144} \times 150 = 285\#$

W = 2210 + 285 = 2495#

$M = 1/10 \times 2495 \times (15)^2 \times 12 = 673,000"\#s$

$A = \frac{M}{(d - \frac{1}{2}t)f_s} = \frac{673,000}{(22 - \frac{1}{2}\ 4)12000} = 2.81$ sq. inches

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Over Supports.

$M = 1/12 \times 2495 \times (15)^2 \times 12 = 561{,}000$"#s

$\frac{M}{bd^2} = 109 = \frac{561{,}000}{b \times (24)^2}$ $b = \frac{561{,}000}{515 \times 109} = 9$"

Area of steel = .0107 x 24 x 9 = 2.31 sq. inches.

End Shear $= \frac{2495 \times 15}{2} = 18{,}700$#

Shear carried by concrete = 12 x 22 x 30 = 7,900

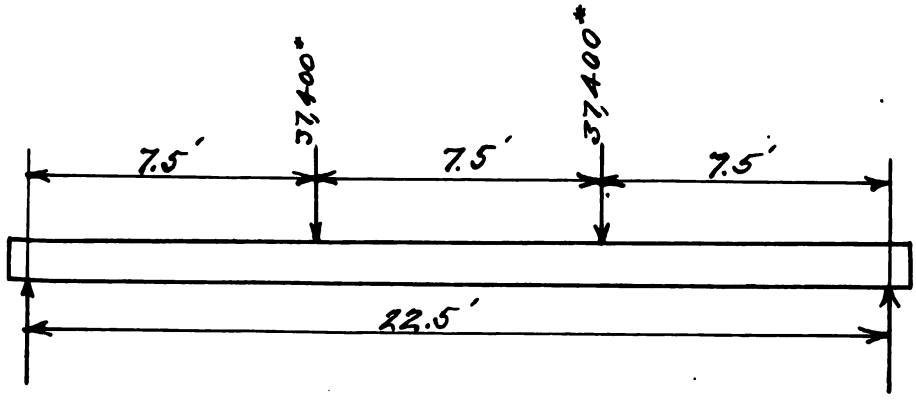
Shear to be carried by steel = 18,700 - 7,900 = 10,800#

Area of steel $= \frac{10800}{12000} = 0.90$ sq. inches

Area of stirrup $= \frac{0.90}{2} = 0.45$"

Average shearing stress $= \frac{18{,}700}{12 \times 22} = 70.1$# ~~1~~ sq. inch

CENTER GIRDERS.



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$$M = \frac{37,400 \times 22.5 \times 12}{9} = 1,120,000"\#s$$

$$\frac{M}{bd^2} = 109 = \frac{1,120,000}{20 \times d^2}$$

$$d = \sqrt{\frac{1,120,000}{20 \times 109}} = 22.7"$$

Negative Moment over Supports.

$$M = \frac{37,400 \times 22.5 \times 12 \times 2}{9} = 2,240,000"\#s$$

$$\frac{M}{bd^2} = 109 = \frac{2,240,000}{20 \times d^2}$$

$$d = \sqrt{\frac{2,240,000}{20 \times 109}} = 32.1" \quad \text{Use } 32\tfrac{1}{4}"$$

Wt per ft. of Beam = $\frac{32.25 \times 20}{144} \times 150 = 671$ #

Pos. D.L. Moment = $\frac{671 \times (22.5)^2 \times 12}{10} = 410,000"\#s$

Neg. D.L. Moment = $\frac{671 \times (22.5)^2 \times 12}{12} = 342,000"\#s$

Total Positive Moment = 1,120,000 + 410,000 = 1,530000"#s

$$\frac{M}{bd^2} = 109 = \frac{1,530,000}{20 \times d^2}$$

$$d = \sqrt{\frac{1,530,000}{20 \times 109}} = 26.5"$$

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Area of steel = .0107 x 20 x 26.5 = 5.67 sq. inches.

Total Neg. Moment = 2,240,000 + 342,000 = 2,582,000"#s

$$\frac{M}{bd^2} = 109 = \frac{2,582,000}{20 \times d^2}$$

$$d = \sqrt{\frac{2,582,000}{20 \times 109}} = 34.5"$$

Area of steel = .0107 x 20 x 34.5 = 7.38 sq. inches.

$$\text{End Shear} = 37,400 + \frac{671 \times 22.5}{2} = 44,950\#$$

Average shearing stress at point of max. moment and

$$\text{max. shear} = \frac{44,950}{28.5 \times 20} = 78 \text{ \# 1 sq. inch.}$$

Shear carried by concrete = 28.5 x 20 x 30 = 17,100

Shear to be carried by steel = 44,950 - 17,100 = 27850#

$$\text{Necessary reinforcement} = \frac{27,850}{12000} = 2.32 \text{ sq. inches.}$$

$$\text{Area of stirrups} = \frac{2.32}{2} = 1.16 \text{ sq. inches.}$$

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SECTION C. (See drawing No. 5)

FLOOR SLAB.

$Z = 6.0'$ $W = 250\#$

$f_c = 600\#$ 1 sq. inch $f_s = 12000\#$ 1 sq. inch.

$M = 1/10 \times 250 \times (6)^2 \times 12 = 10{,}800''\#s$

$$\frac{M}{bd^2} = 109 = \frac{10800}{12 \times d^2}$$

$$d = \sqrt{\frac{10{,}800}{12 \times 109}} = 2.87''$$

Wt of lin. ft. of Slab $= \frac{12 \times 2.87}{144} \times 150 = 35.9\#$

$W = 250 + 36 = 286\#$

$M = 1/10 \times 286 \times (6)^2 \times 12 = 12{,}350''\#s$

$$\frac{M}{bd^2} = 109 \quad \frac{12{,}350}{12 \times d^2}$$

$$d = \sqrt{\frac{12{,}350}{12 \times 109}} = 3.075'' \quad \text{Use } 4''$$

Area of steel $= .0107 \times 4 \times 12 = 0.514$ sq. inches.

Negative Moment $= 1/12 \times 286 \times (6)^2 \times 12 = 10{,}300''\#s$

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$$\frac{M}{bd^2} = 109 \quad \frac{10,300}{12 \times d^2}$$

$$d = \sqrt{\frac{10,300}{12 \times 109}} = 2.79''$$

Area of steel = .0107 x 2.8 x 12 = 0.36 sq. inches.

CROSS BEAMS.

$$d = t\left(\frac{f_s}{nf_c} + 1\right) \qquad d = 4\left(\frac{12,000}{15 \times 600} + 1\right) = 9.34$$

$$W = 286 \times 6 = 1715$$

$$M = 1/10 \times 1715 \times (15)^2 \times 12 = 464,000''\#s$$

$$C = \frac{M}{(d - \frac{1}{2}t)} = \frac{464,000}{(20 - \frac{1}{2}\,4)} = 25,800\#$$

$$b = \frac{2C}{tf_c} = \frac{2 \times 25,800}{4 \times 600} = 21.5''$$

$$b = 12$$

$$\text{Wt per ft. of beam} = \frac{12 \times 20}{144} \times 150 = 250\#$$

$$W = 1715 + 250 = 1965\#$$

$$M = 1/10 \times 1965 \times (15)^2 \times 12 = 530,000''\#s$$

$$A = \frac{M}{(d - \frac{1}{2}t)f_s} = \frac{530,000}{(20 - \frac{1}{2}\,4)12000} = 2.21 \text{ sq. inches.}$$

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Negative Moment over Support.

$M = 1/12 \times 1965 \times (15)^2 \times 12 = 441{,}000$"#s

$\frac{M}{bd^2} = 109 = \frac{441{,}000}{b \times (20)^2} = b = \frac{441{,}000}{(20)^2 \times 109} = 10.13$" Use 12"

Area of steel = .0107 x 20 x 12 = 2.57 sq. inches.

End Shear = $\frac{1965 \times 15}{2} = 14{,}750$#

Average shearing stress = $\frac{14{,}750}{12 \times 20} = 61.5$#

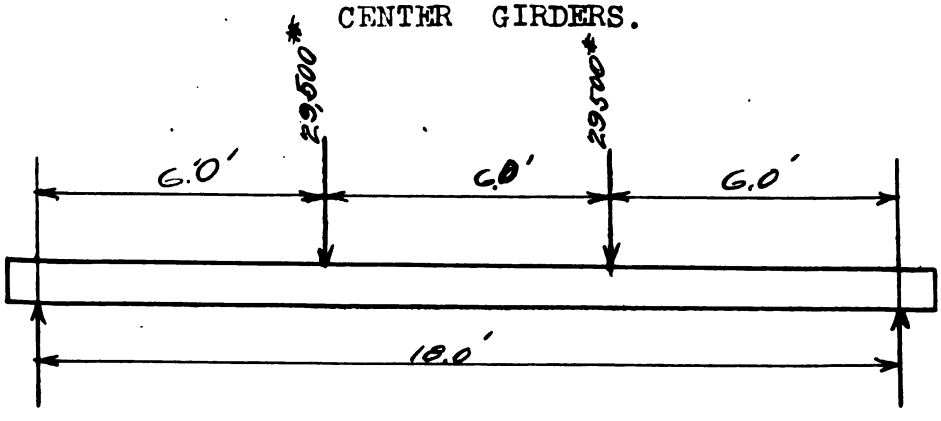
Shear carried by concrete = 12 x 20 x 30 = 7,200#

Shear to be carried by steel = 14750 - 7,200 = 7,550#

Area of steel = $\frac{7{,}550}{12000} = 0.63$ sq. inches.

Area of stirrup = $\frac{0.63}{2} = 0.315$ sq. inches.

CENTER GIRDERS.



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$$M = \frac{29,500 \times 18 \times 12}{9} = 708,000"\#s$$

Negative Moment over supports

$$M = \frac{2 \times 29,500 \times 18 \times 12}{9} = 1,416,000"\#s$$

$$\frac{M}{bd^2} = 109 = \frac{1,416,000}{18 \times d^2}$$

$$d = \sqrt{\frac{1,416,000}{18 \times 109}} = 26.9"$$

Wt per ft. ofBeam $= \frac{18 \times 24}{144} \times 150 = 450\#$

Pos. P.L. Moment $= \frac{450 \times (18)^2 \times 12}{10} = 175,000"\#s$

Neg. P.L. Moment $= \frac{450 \times (18)^2 \times 12}{12} = 146,000"\#s$

Total Pos. Moment = 708,000 + 175,000 = 883,000"#s

$$\frac{M}{bd^2} = 109 = \frac{883,000}{18 \times d^2}$$

$$d = \sqrt{\frac{883,000}{18 \times 109}} = 21.2"$$

Area of steel = .0107 x 18 x 21.2 = 4.08 sq. inches.

Total Neg. Moment = 1,416,000 + 146,000 = 1,562,000"#s

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$$\frac{M}{bd^2} = 109 = \frac{1,562,000}{18 \times d^2}$$

$$d = \sqrt{\frac{1,562,000}{18 \times 109}} = 28.2''$$

Area of steel = .0107 x 18 x 28.2 = 5.43 sq. inches.

End Shear = 29,500 + $\frac{490 \times 18}{2}$ = 33.910 #

Average shearing stress at least section =

$$\frac{33,910}{21.2 \times 18} = 89\#$$

Shear carried by concrete = 18 x 21.2 x 30 = 11,450#

Shear to be carried by steel = 33,910 - 11,450 = 22460#

Area of steel = $\frac{22,460}{12000}$ = 1.88 sq. inches.

Area of stirrup = $\frac{1.88}{2}$ = 0.94 sq. inches.

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SECTION D. (See drawing No. 6)

FLOOR SLAB.

$l = 7.33$ $W = 350\#$

$f_c = 600\#$ 1 sq. inch $f_s = 12000\#$ 1 sq. inch. $n = 15$

$M = 1/10 \times 350 \times (7.33)^2 \times 12 = 22{,}600$"#s

$$\frac{M}{bd^2} = 109 = \frac{22{,}600}{12 \times d^2}$$

$$d = \sqrt{\frac{22{,}600}{12 \times 109}} = 4.16" \text{ or } 4.25"$$

Wt of lin. ft. of Slab = $\frac{12 \times 4.25}{144} \times 150 = 53.1\#$ or 55

$W = 350 + 55 = 405\#$

$M = 1/10 \times 403 \times (7.33)^2 \times 12 = 26{,}100$"#s

$$\frac{M}{bd^2} = 109 = \frac{26{,}100}{12 \times d^2}$$

$$d = \sqrt{\frac{26{,}100}{12 \times 109}} = 4.46" \text{ Use } 4\tfrac{3}{4}"$$

Area of steel = .0107 x 4.75 x 12 = 0.59 sq. inches

Negative Moment = $1/12 \times 405 \times (7.33)^2 \times 12 = 21{,}800$"#s

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$$\frac{M}{bd^2} = 109 = \frac{21,800}{12 \times d^2}$$

$$d = \sqrt{\frac{21,800}{12 \times 109}} = 4.07 \text{ or } 4\tfrac{1}{4}''$$

Area of steel = .0107 x 4.25 x 12 = 0.55 sq. inches.

CROSS BEAMS.

$$d = t\left(\frac{f_s}{nf_c} + 1\right) \quad d = 4.5\left(\frac{12,000}{15 \times 600} + 1\right) = 11.7''$$

$$W = 405 \times 7.33 = 2970\#$$

$$M = 1/10 \times 2970 \times (15)^2 \times 12 = 802,000''\#s$$

$$C = \frac{M}{(d - \frac{1}{2}t)} = \frac{802,000}{(24 - \frac{4.5}{2})} = \frac{802,000}{21.75} = 37,000\#$$

$$b = \frac{2C}{tf_c} = \frac{2 \times 37,000}{4.5 \times 600} = 27.4''$$

$$b = 12''$$

$$\text{Wt. per ft. of beam} = \frac{12 \times 24}{144} \times 150 = 300\#$$

$$W = 2970 + 300 = 3270\#$$

$$M = 1/10 \times 3270 \times (15)^2 \times 12 = 881,000''\#s$$

$$A = \frac{M}{(d - \frac{t}{2})f_s} = \frac{881,000}{(24 - \frac{4.5}{2})12000} = 3.38 \text{ sq. inches.}$$

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Negative Moment over support.

$M = 1/12 \times 3270 \times (15)^2 \times 12 = 735{,}000$"#s

$$\frac{M}{bd^2} = 109 = \frac{735{,}000}{b \times (24)^2}$$

$$b = \frac{735{,}000}{109 \times (24)^2} = 11.7 \text{ " or } 12\text{"}$$

Area of steel = .0107 x 12 x 24 = 3.08 sq. inches.

$$\text{End Shear} = \frac{3270 \times 15}{2} = 24{,}500\#$$

$$\text{Average shearing stress} = \frac{24{,}500}{12 \times 24} = 85\#$$

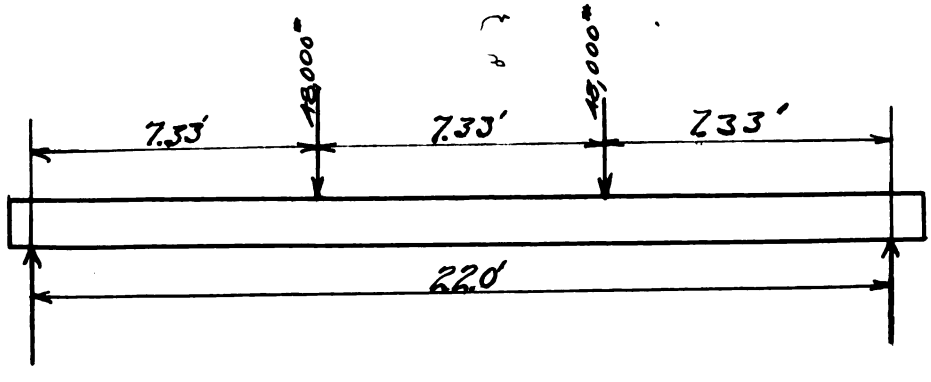
Shear carried by concrete = 14 x 24 x 30 = 10,100#

Shear to be carried by steel = 24,500 - 10,100 = 14400#

$$\text{Area of steel} = \frac{14{,}100}{12000} = 1.18 \text{ sq. inches.}$$

$$\text{Area of stirrup} = \frac{1.18}{2} = .59 \text{ sq. inches.}$$

CENTER GIRDERS.



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$$M = \frac{48000 \times 22 \times 12}{9} = 1{,}268{,}000''\#s$$

$$\text{Negative Moment} = \frac{2 \times 48000 \times 22 \times 12}{9} = 2536000''\#s$$

$$\frac{M}{bd^2} = 109 = \frac{2{,}536{,}000}{20 \times d^2}$$

$$d = \sqrt{\frac{2{,}536{,}000}{20 \times 109}} = 34.1''$$

$$\text{Wt. per ft. of Beam} = \frac{20 \times 34.1}{144} \times 150 = 710\#$$

$$\text{Pos. D.L. Moment} = \frac{710 \times (22)^2 \times 12}{10} = 412000''\#s$$

$$\text{Negative D.L. Moment} = \frac{710 \times (22)^2 \times 12}{12} = 344{,}000''\#s$$

Total Pos. Moment = 1,268,000 + 412,000 = 1,680,000"#s

$$\frac{M}{bd^2} = 109 = \frac{1{,}680{,}000}{20 \times d^2}$$

$$d = \sqrt{\frac{1{,}680{,}000}{20 \times 109}} = 27.8''$$

Area of steel = .0107 x 20 x 28 = 6.0 sq. inches.

Total Neg. Moment = 2,536,000 + 344,000 = 2,880,000"#s

$$\frac{M}{bd^2} = 109 = \frac{2880000}{20 \times d^2}$$

$$d = \sqrt{\frac{2{,}880{,}000}{20 \times 109}} = 36.3''$$

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Area of steel = .0107 x 36.3 x 20 = 7.77 sq. inches.

End Shear = 48,000 + $\frac{710 \times 22}{2}$ = 55,810#

Average shearing stress at least section = $\frac{55,810}{28 \times 20}$ =

100#

Shear carried by concrete = 20 x 36.3 x 30 = 21,800#

Shear to be carried by steel = 55,810 - 21,800 = 34010#

Web reinforcement = $\frac{34,010}{12000}$ = 2.84 sq. inches.

Area of stirrup = $\frac{2.84}{2}$ = 1.42 sq. inches.

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SECTION E. (See Drawing No. 7)

FLOOR SLAB.

$Z = 7.25'$ $W = 350\#$

$f_c = 600$ $f_s = 12000$ $n = 15$

$M = 1/10 \times 350 \times (7.25)^2 \times 12 = 221{,}000''\#s$

$\frac{M}{bd^2} = 109 = \frac{221{,}000}{12 \times d^2}$

$d = \sqrt{\frac{221{,}000}{12 \times 109}} = 4.11$

Wt. of lin. ft. of Slab = $\frac{12 \times 4.11}{144} \times 150 = 52\#$

$W = 350 + 52 = 402\#$

$M = 1/10 \times 402 \times (7.25)^2 \times 12 = 250{,}000''\#s$

$\frac{M}{bd^2} = 109 = \frac{250{,}000}{12 \times d^2}$

$d = \sqrt{\frac{250{,}000}{12 \times 109}} = 4.375''$ Use $4\frac{1}{2}''$

Area of steel = .0107 x 12 x 4.375 = .56 sq. inches.

Negative Moment = $1/12 \times 402 \times (7.25)^2 \times 12 = 208{,}500''\#s$

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$$\frac{M}{bd^2} = 109 = \frac{208,500}{12 \times d^2}$$

$$d = \sqrt{\frac{208,500}{12 \times 109}} = 4''$$

Area of steel = .0107 x 12 x 4 = .515 sq. inches.

CROSS BEAMS.

$$d = t\left(\frac{f_s}{nf_c} + 1\right) \qquad d = 4.375\left(\frac{12000}{15 \times 600} + 1\right) = 10.2''$$

W = 402 x 7.25 = 2920#

$$M = 1/10 \times 2920 \times (17.25)^2 \times 12 = 1,043,000''\#s$$

$$C = \frac{M}{(d - \frac{1}{2}t)} = \frac{1,043,000}{(24 - \frac{1}{2}\ 4.325)} = 47,800\#$$

$$b = \frac{2C}{tf_c} = \frac{2 \times 47,800}{4.375 \times 600} = 36.4''$$

b = 16"

$$\text{Wt per ft. of Beam} = \frac{24 \times 16}{144} \times 150 = 400\#$$

W = 2920 + 400 = 3320#

$$M = 1/10 \times 3320 \times (17.25)^2 \times 12 = 1,189,000''\#s$$

$$A = \frac{M}{(d - \frac{1}{2}t)f_s} = \frac{1,189,000}{(24 - \frac{4.5}{2})} = 4.55 \text{ sq. inches}$$

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Over Supports.

Negative Moment = 1/12 x 3320 x (17.25) x 12 = 990,000#

$$\frac{M}{bd^2} = 109 = \frac{990,000}{16 \times d^2}$$

$$d = \sqrt{\frac{990,000}{16 \times 109}} = 23.8''$$

Area of steel = .0107 x 16 x 23.8 = 4.07 sq. inches.

$$\text{End Shear} = \frac{3320 \times 17.25}{2} = 28,600\#$$

$$\text{Average shearing stress} = \frac{28,600}{14 \times 24} = 85\#$$

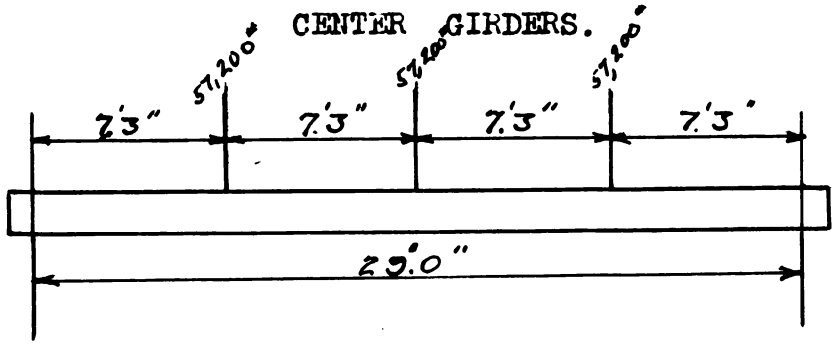
Shear carried by concrete = 14 x 24 x 30 = 10,100#

Shear to be carried by steel = 18,500#

$$\text{Area of steel} = \frac{18,500}{12,000} = 1.54 \text{ sq. inches.}$$

$$\text{Area of stirrup} = \frac{1.54}{2} = .77 \text{ sq. inches.}$$

CENTER GIRDERS.



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$$M = \frac{3 \times 57{,}200 \times 29 \times 12}{16} = 3{,}735{,}000''\#s$$

$$\frac{M}{bd^2} = 109 = \frac{3{,}735{,}000}{28 \times d^2}$$

$$d = \sqrt{\frac{3{,}735{,}000}{28 \times 109}} = 35.0''$$

Negative Moment over support.

$$M = \frac{5 \times 57{,}200 \times 29 \times 12}{16} = 6{,}230{,}000''\#s$$

$$\frac{M}{bd^2} = 109 = \frac{6{,}230{,}000}{28 \times d^2}$$

$$d = \sqrt{\frac{6{,}230{,}000}{28 \times 109}} = 45.0''$$

Wt per ft. of Beam $= \frac{40 \times 28}{144} \times 150 = 1168\#$

Pos. D.L. Moment $= \frac{1168 \times (29)^2 \times 12}{10} = 1{,}178{,}000''\#s$

Neg. D.L. Moment $= \frac{1168 \times (29)^2 \times 12}{12} = 981{,}000''\#s$

Total Pos. Moment = 3,735,000 + 1,178,000 = 4,913,000"#s

$$\frac{M}{bd^2} = 109 = \frac{4{,}913{,}000}{28 \times d^2}$$

$$d = \sqrt{\frac{4{,}913{,}000}{28 \times 109}} = 40.1''$$

Area of steel = .0107 x 28 x 40.1 = 12.0 sq. inches.

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Total Neg. Moment = 6,230,000 + 981,000 = 7,211,000"#s

$$\frac{M}{bd^2} = 109 = \frac{7,211,000}{28 \times d^2}$$

$$d = \sqrt{\frac{7,211,000}{28 \times 109}} = 48.3"$$

Area of steel = .0107 x 28 x 48.3 = 14.5 sq. inches.

$$\text{End Shear} = 85,800 + \frac{1,168 \times 29}{2} = 102,740\#$$

$$\text{Average Shearing stress} = \frac{102,740}{28 \times 43} = 85.\#$$

Shear carried by concrete = 28 x 43 x 30 = 36,100

Shear to be carried by steel = 102,740 - 36,100 = 66640

$$\text{Area of steel} = \frac{66,640}{12000} = 5.55 \text{ sq. inches.}$$

$$\text{Area of stirrups} = \frac{5.55}{2} = 2.77$$

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Design of Roof

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SECTION A. (See drawing No. 8)

DESIGN OF ROOF.

Pitch 1" in 1' Angle 5°

Leads to be carried per sq. ft. of roof

Roof covering (tar and gravel over 4 thickness of felt) = = 9.5#

Snow = 22.0

Wind press = 5.2

Total = 36.7#

Use 37#

Slabs.

$$M = \frac{37 \times (17.25)^2 \times 12}{12} = 13,180"\#s$$

$$\frac{M}{bd^2} = 109 = \frac{13,180}{12 \times d^2}$$

$$d = \sqrt{\frac{13,180}{12 \times 109}} = 3.175"$$

Wt. of lin. ft. of Slab $= \frac{4.5 \times 12}{144} \times 150 = 54\#$

$W = 37 + 54 = 91\#$

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$$M = \frac{91 \times (17.25)^2 \times 12}{10} = 32{,}500''\#s$$

$$\frac{M}{bd^2} = 109 = \frac{32{,}500}{12 \times d^2}$$

$$d = \sqrt{\frac{32{,}500}{12 \times 109}} = 5''$$

Area of steel = .0107 x 5 x 12 = 0.641 sq. inches.

Over Supports.

$$M = \frac{91 \times (17.25)^2 \times 12}{12} = 27{,}100''\#s$$

$$\frac{M}{bd^2} = 109 = \frac{27{,}100}{12 \times d^2}$$

$$d = \sqrt{\frac{27{,}100}{12 \times 109}} = 4.55''$$

Area of steel = .0107 x 4.55 x 12 = 0.585 sq. inches.

CROSS BEAMS.

W = 95 x 17.25 = 1640#

$$M = \frac{1640 \times (22.5)^2 \times 12}{10} = 995{,}000''\#s$$

$$\frac{M}{bd^2} = 109 = \frac{995{,}000}{16 \times d^2}$$

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$$d = \sqrt{\frac{995,000}{16 \times 109}} = 23.8$$

Wt of lin. ft. of Beam $= \frac{23.8 \times 16}{144} \times 150 = 398\#$

$W = 1640 + 400 = 2040\#$

$$M = \frac{2040 \times 22.5 \times 12}{10} = 1,240,000''\#s$$

$$\frac{M}{bd^2} = 109 = \frac{1,240,000}{16 \times d^2}$$

$$d = \sqrt{\frac{1,240,000}{16 \times 109}} = 26.8''$$

Area of steel = .0107 x 16 x 26.8 = 4.69 sq. inches.

Over Supports.

$$M = \frac{2040 \times 22.5 \times 12}{12} = 1,031,000''\#s$$

$$\frac{M}{bd^2} = 109 = \frac{1,031,000}{16 \times d^2}$$

$$d = \sqrt{\frac{1,031,000}{16 \times 109}} = 24.4''$$

Area of steel = .0107 x 16 x 24.4 = 4.17 sq. inches.

End Shear $= \frac{2040 \times 22.5}{2} = 23,000\#$

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Average shearing stress $= \frac{23,000}{16 \times 27} = 53.1\#$ sq. inch.

Shear carried by concrete = 16 x 27 x 30 = 1,300#

Necessary Web reinforcement $= \frac{10,000}{12,000} = 0.835$ sq. inch

Area of stirrup $= \frac{.835}{2} = .42$ sq. inches.

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SECTION B, C, & D. (See drawing No. 9)

ROOF.

Slab.

W = 37# per sq. foot.

$$M = \frac{37 \times (15)^2 \times 12}{10} = 9.980 \text{ "\#s}$$

$$\frac{M}{bd^2} = 109 = \frac{9,980}{12 \times d^2}$$

$$d = \sqrt{\frac{9,980}{12 \times 109}} = 2.77"$$

Wt. of lin. ft. of Slab = $\frac{4 \times 12}{144} \times 150 = 50\#$

W = 37 + 50 = 87#

$$M = \frac{87 \times (15)^2 \times 12}{10} = 2,350 \text{"\#s}$$

$$\frac{M}{bd^2} = 109 = \frac{2,350}{12 \times d^2}$$

$$d = \sqrt{\frac{2,350}{12 \times 109}} = 4.24"$$

Area of steel = .0107 x 4.25 x 12 = 0.545 sq. inches.

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Over Supports.

$$M = \frac{87 \times 15^2 \times 12}{10} = 1{,}960 \text{ "\#s}$$

$$\frac{M}{bd^2} = 109 = \frac{1{,}960}{12 \times d^2}$$

$$d = \sqrt{\frac{1{,}960}{12 \times 109}} = 3.88"$$

Area of steel = .0107 x 3.88 x 12 = 0.5 sq. inches.

CROSS BEAMS.

$$W = 90 \times 15 = 1350\#$$

$$M = \frac{1350 \times (22.5)^2 \times 12}{10} = 765{,}000\text{"\#s}$$

$$\frac{M}{bd^2} = 109 = \frac{765{,}000}{14 \times d^2}$$

$$d = \sqrt{\frac{765{,}000}{14 \times 109}} = 22.6"$$

Wt of lin. ft. of Beam = $\frac{25 \times 14}{144} \times 150 = 365\#$

$$W = 1350 + 365 = 1720\#$$

$$M = \frac{1720 \times (22.5)^2 \times 12}{10} = 1{,}045{,}000\text{"\#s}$$

$$\frac{M}{bd^2} = 109 = \frac{1{,}045{,}000}{14 \times d^2}$$

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$$M = \frac{91 \times (17.25)^2 \times 12}{10} = 32,500''\#s$$

$$\frac{M}{bd^2} = 109 = \frac{32,500}{12 \times d^2}$$

$$d = \sqrt{\frac{32,500}{12 \times 109}} = 5''$$

Area of steel = .0107 x 5 x 12 = 0.641 sq. inches.

Over Supports.

$$M = \frac{91 \times (17.25)^2 \times 12}{12} = 27,100''\#s$$

$$\frac{M}{bd^2} = 109 = \frac{27,100}{12 \times d^2}$$

$$d = \sqrt{\frac{27,100}{12 \times 109}} = 4.55''$$

Area of steel = .0107 x 4.55 x 12 = 0.585 sq. inches.

CROSS BEAMS.

W = 95 x 17.25 = 1640#

$$M = \frac{1640 \times (22.5)^2 \times 12}{10} = 995,000''\#s$$

$$\frac{M}{bd^2} = 109 = \frac{995,000}{16 \times d^2}$$

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$$d = \sqrt{\frac{995,000}{16 \times 109}} = 23.8$$

Wt of lin. ft. of Beam $= \frac{23.8 \times 16}{144} \times 150 = 398\#$

$W = 1640 + 400 = 2040\#$

$$M = \frac{2040 \times 22.5 \times 12}{10} = 1,240,000''\#s$$

$$\frac{M}{bd^2} = 109 = \frac{1,240,000}{16 \times d^2}$$

$$d = \sqrt{\frac{1,240,000}{16 \times 109}} = 26.8''$$

Area of steel = .0107 x 16 x 26.8 = 4.69 sq. inches.

Over Supports.

$$M = \frac{2040 \times 22.5 \times 12}{12} = 1,031,000''\#s$$

$$\frac{M}{bd^2} = 109 = \frac{1,031,000}{16 \times d^2}$$

$$d = \sqrt{\frac{1,031,000}{16 \times 109}} = 24.4''$$

Area of steel = .0107 x 16 x 24.4 = 4.17 sq. inches.

End Shear $= \frac{2040 \times 22.5}{2} = 23,000\#$

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Average shearing stress $= \frac{23,000}{16 \times 27} = 53.1\#$ ~~1~~ sq. inch.

Shear carried by concrete = 16 x 27 x 30 = 1,300#

Necessary Web reinforcement $= \frac{10,000}{12,000} = 0.835$ sq. inch

Area of stirrup $= \frac{.835}{2} = .42$ sq. inches.

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SECTION B, C, & D. (See drawing No. 9)

ROOF.

Slab.

W = 37# per sq. foot.

$$M = \frac{37 \times (15)^2 \times 12}{10} = 9.980 \text{ "\#s}$$

$$\frac{M}{bd^2} = 109 = \frac{9,980}{12 \times d^2}$$

$$d = \sqrt{\frac{9,980}{12 \times 109}} = 2.77"$$

Wt. of lin. ft. of Slab = $\frac{4 \times 12}{144} \times 150 = 50\#$

W = 37 + 50 = 87#

$$M = \frac{87 \times (15)^2 \times 12}{10} = 2,350\text{"\#s}$$

$$\frac{M}{bd^2} = 109 = \frac{2,350}{12 \times d^2}$$

$$d = \sqrt{\frac{2,350}{12 \times 109}} = 4.24"$$

Area of steel = .0107 x 4.25 x 12 = 0.545 sq. inches.

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Over Supports.

$$M = \frac{87 \times 15^2 \times 12}{10} = 1{,}960 \text{ "\#s}$$

$$\frac{M}{bd^2} = 109 = \frac{1{,}960}{12 \times d^2}$$

$$d = \sqrt{\frac{1{,}960}{12 \times 109}} = 3.88"$$

Area of steel = .0107 x 3.88 x 12 = 0.5 sq. inches.

CROSS BEAMS.

$$W = 90 \times 15 = 1350\#$$

$$M = \frac{1350 \times (22.5)^2 \times 12}{10} = 765{,}000\text{"\#s}$$

$$\frac{M}{bd^2} = 109 = \frac{765{,}000}{14 \times d^2}$$

$$d = \sqrt{\frac{765{,}000}{14 \times 109}} = 22.6"$$

Wt of lin. ft. of Beam = $\frac{25 \times 14}{144} \times 150 = 365\#$

$$W = 1350 + 365 = 1720\#$$

$$M = \frac{1720 \times (22.5)^2 \times 12}{10} = 1{,}045{,}000\text{"\#s}$$

$$\frac{M}{bd^2} = 109 = \frac{1{,}045{,}000}{14 \times d^2}$$

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$$d = \sqrt{\frac{1,045,000}{14 \times 109}} = 26.2$$

Area of steel = .0107 x 14 x 26.2 = 3.92 sq. inches.

Over Supports.

$$M = \frac{1720 \times (22.5)^2 \times 12}{12} = 870,000''\#s$$

$$\frac{M}{bd^2} = 109 = \frac{870,000}{14 \times d^2}$$

$$d = \sqrt{\frac{870,000}{14 \times 109}} = 24''$$

Area of steel = .0107 x 14 x 24 = 3.7 sq. inches.

$$\text{End Shear} = \frac{1720 \times 22.5}{2} = 19,400\#$$

$$\text{Average shearing stress} = \frac{19,400}{14 \times 26.2} = 53 \# / \text{sq. inch}$$

Shear carried by concrete = 30 x 14 x 26.2 = 11,000"

$$\text{Necessary web reinforcement} = \frac{8,400}{12000} = 0.7 \text{ sq. inches.}$$

$$\text{Area of stirrup} = \frac{0.70}{2} = 0.35 \text{ sq. inches.}$$

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Design of Columns

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SECTION A

See Drawing No. 10

Floor	Load	Area Req'd sq. ins.	Area Used sq. ins.	Steel Req'd sq. ins.	Steel Used sq. ins.
		CENTER COLUMNS.			
4	45,000	79 sq"	144 sq."	0.85 sq."	1.54 sq."
3	202,300	365	400	3.80	4.28
2	407,800	714	730	7.64	7.81
1	617,400	1080	1090	10.16	10.17
		SIDE COLUMNS.			
4	22500	40	144	0.43	1.54
3	102,000	179	196	1.92	2.10
2	204,700	360	361	3.85	3.86
1	309,300	542	576	5.80	6.16
		CORNER COLUMNS.			
4	11,300	20	144	0.21	1.54
3	52,100	92	144	0.98	1.54
2	92,900	163	169	1.70	1.81
1	134,100	236	256	2.53	2.74

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SECTION B

See Drawing No. 11

CENTER COLUMNS.

Floor	Load	Area Req'd sq. Ins.	Area Used sq. ins.	Steel Req'd sq. ins.	Steel Used sq. ins.
4	36,200	60	144	0.64	1.54
3	173,700	298	324	3.19	3.47
2	314,300	539	576	5.76	6.17
1	457,500	784	784	8.40	8.40

SIDE COLUMNS.

4	18,100	32	144	0.34	1.54
3	87,000	153	169	1.64	1.81
2	159,200	280	289	3.00	3.10
1	229,300	400	400	4.27	4.27

CORNER COLUMNS.

4	10,100	18	144	0.193	1.54

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CORNER COLUMNS. (continued)

Floor	Load	Area Req'd sq. ins.	Area Used Sq. ins.	Steel Req'd sq. ins.	Steel Used sq. ins.
3	44,000	77	144	0.82	1.54
2	79,100	139	144	1.49	1.54
1	112,100	197	225	2.11	2.41

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CENTER COLUMNS BETWEEN B & C. (See Drawing No. 12)

Floor	Load	Area Req'd sq. ins.	Area Used Sq. ins.	Steel Req'd sq. ins.	Steel Used Sq. ins.
4	32,800	57.5	144	0.615	1.54
3	157,200	276	289	2.85	3.09
2	284,500	500	529	5.35	5.65
1	414,600	726	729	7.76	7.80

SIDE COLUMNS BETWEEN B & C.

4	16,400	29	144	0.31	1.54
3	78,100	137	144	1.47	1.54
2	143,200	252	256	2.70	2.73
1	208,300	366	400	3.92	4.28

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CENTER COLUMNS BETWEEN C & D.

	Floor Load	Area Req'd sq. ins.	Area Used Sq. ins.	Steel Req'd sq. ins.	Steel Used sq. ins.
4	32800	58	144	0.62	1.54
3	151,200	276	289	1.89	2.02
2	284,500	500	529	5.35	5.65
1	434,200	762	784	8.15	8.40

SIDE COLUMNS BETWEEN C & D.

4	16,400	29	144	0.31	1.54
3	78,100	137	144	1.47	1.54
2	143,200	262	289	2.80	3.09
1	218,100	383	400	4.10	4.28

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SECTION E (See Drawing No. 14)

Floor	Load	Area req'd sq. ins.	Area Used Sq. ins.	Steel req'd sq. ins.	Steel Used sq. ins.
CENTER COLUMNS.					
1	322,000	565	576	6.05	6.16
COLUMNS BETWEEN SECTIONS A & E.					
4	22,500	40	144	.43	1.54
3	102,000	179	196	1.91	2.10
2	234,600	412	441	4.41	4.73
1	504,300	884	900	9.45	9.63

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CORNER COLUMN FOOTING. (Section A.)

Area of footing $= \frac{134,100}{4000} = 33.6$ sq. feet. Use 6' x 6"

Moment at Center $= \frac{4000 \times (3)^2 \times 12}{2} = 216,000$"#s

$\frac{M}{bd^2} = 109 = \frac{216,000}{12 \times d^2}$

$d = \sqrt{\frac{216,000}{12 \times 109}} = 13" = 1'1"$

Area of steel = .0107 x 12 x 13 = 1.68 sq. inches.

Shear = 4,000 x 3 = 12,000#

Average shearing stress $= \frac{12000}{12 \times 13} = 77$# per sq. in

Shear carried by concrete = 12 x 13 x 30 = 4,680#

Shear to be carried by steel = 12,000 - 4,680 = 7,320#

Area of steel $= \frac{7,320}{12,000} = .61$ sq. inches.

CORNER COLUMN CANTILEVER GIRDER.

M = 134,100 x 2.33 x 12 = 3,750,000"#s

$\frac{M}{bd^2} = 109 = \frac{3,750,000}{36 \times d^2}$

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$$d = \sqrt{\frac{3,750,000}{36 \times 109}} = 31" = 2'7"$$

Wt of lin. ft. of beam = $\frac{36 \times 31}{144} \times 150 = 1,120\#$

P.L. Moment = $\frac{1,120 \times (3)^2 \times 12}{2} = 60,500"\#s$

Total Moment = 3,750,000 + 60,500 = 3,810,500

$$\frac{M}{bd^2} = 109 = \frac{3,810,500}{36 \times d^2}$$

$$d = \sqrt{\frac{3,810,500}{36 \times 109}} = 32" = 2'8"$$

Area of steel = .0107 x 36 x 32 = 12.3 sq. inches.

End Shear = 134,100 + 1,120 x 3 = 137,500#

Shear carried by concrete = 36 x 32 x 30 = 34,600#

Shear to be carried by steel = 137,500 - 34,600 =

102,900#

Area of steel = $\frac{102,900}{12,000}$ = 8.56 sq. inches.

Shear at end of long area = $\frac{3,810,500}{20,167 \times 12}$ = 15800#.

Area of beam shearing stress 100" = $\frac{15,800}{100}$ = 158 sq.in.

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Depth of Beam = $\frac{158}{36}$ = 5" Use 12"

Shear carried by concrete = 12 x 36 x 30 = 13,000

Shear to be carried by steel = 15,800 - 13,000 = 28000

Area of steel = $\frac{2,800}{12000}$ = 0.24 sq. inches.

COLUMNS BETWEEN B & C AND C & D.

SIDE COLUMN CANTILEVER GIRDERS.

(See Drawing No. 18)

M = 218,100 x 2.42 x 12 = 6,350,000 "#s

$$\frac{M}{bd^2} = 109 = \frac{6,350,000}{36 \times d^2}$$

$$d = \sqrt{\frac{6,350,000}{36 \times 109}} = 41" = 3'5"$$

Wt. of lin. ft. of beam = $\frac{36 \times 41}{144}$ x 150 = 1540#

P.L. Moment = $\frac{1540 \times (2.42)^2 \times 12}{2}$ = 540,000"#s

Total Moment = 6,350,000 + 54,000 = 6,404000"#s

$$\frac{M}{bd^2} = 109 = \frac{6,404,000}{36 \times d^2}$$

$$d = \sqrt{\frac{6,404,000}{36 \times 109}} = 41" = 3'5"$$

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Area of steel = .0107 x 36 x 41 = 15.8 sq. inches.

End Shear = 218,100 + 1540 x 3.25 = 223,100#

Average shearing stress $= \frac{223,100}{36 \times 41}$ = 151 #s per sq.in.

Shear carried by concrete = 36 x 41 x 30 = 44,250#

Shear to be carried by steel = 223,100 - 44,250 = 178850#

Area of steel = $\frac{178,850}{12000}$ = 14.8 sq. inches.

Shear end of long arm $= \frac{6,404,000}{12 \times 12.58}$ = 40,500#

Area of beam shearing stress of 100" $= \frac{40,500}{100} =$

405 sq. inches.

Depth of beam = $\frac{405}{36}$ = 11.2 Use 12"

Shear carried by concrete = 12 x 36 x 30 = 12,970#

Shear to be carried by steel = 40,500 - 12,970 =

27,530#

Area of steel = $\frac{27,530}{12,000}$ = 2.3 sq. inches.

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COLUMNS BETWEEN SECTIONS B & C AND C & D.

SIDE COLUMN FOOTINGS.

Area of footing $= \frac{218,100}{4,000} = 54.6$ sq. inches Use

7.5' x 7.5'

Moment at Center $= \frac{4000 \times (3.25)^2 \times 12}{2} = 25500$"#s

$\frac{M}{bd^2} = 109 = \frac{255,000}{12 \times d^2}$

$d = \sqrt{\frac{255,000}{12 \times 109}} = 14" = 1'2"$

Area of steel = .0107 x 12 x 14 = 1.80 sq. inches.

Shear = 4,000 x 3.25 = 13,000#

Average shearing stress $= \frac{13,000}{12 \times 14} = 77.5$# per sq. in.

Shear carried by concrete = 12 x 14 x 30 = 5,040#

Shear to be carried by steel = 13,000 - 5000 = 8000#

Area of steel $= \frac{8,000}{12,000} = .66$ sq. inches.

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CENTER COLUMN FOOTINGS.

Area of footing $= \frac{434,200}{4000} = 108.5$ sq. inch. Use

11' x 11'

Moment at center $= \frac{4000 \times (5.5)^2 \times 12}{2} = 730200$

$\frac{M}{bd^2} = 109 = \frac{730,200}{12 \times d^2}$

$d = \sqrt{\frac{730,000}{12 \times 109}} = 24" = 2'0"$

Area of steel = .0107 x 12 x 24 = 3.08 sq. inches.

Shear = 4,000 x 5.5 = 22,000

Average shearing stress $= \frac{22,000}{12 \times 24} = 76.5\#$ per sq. in

Shear carried by concrete = 12 x 24 x 30 = 8,650

Shear to be carried by steel = 22,000 - 8,650 = 13350#

Area of steel $= \frac{13350}{12000} = 1.11$ sq. inches.

SIDE COLUMN FOOTINGS. (Section A.)
(See Drawing No. 15)

Area of footing $= \frac{309,300}{4000} = 78$ sq. ft. Use 9' x9"

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Moment at center = $\frac{4000 \times (4.5)^2 \times 12}{2}$ = 486,000"#

$\frac{M}{bd^2} = 109 = \frac{486,000}{12 \times d^2}$

$d = \sqrt{\frac{486,000}{12 \times 109}} = 20" = 1'8"$

Area of steel = .0107 x 20 x 12 = 2.57 sq. inches.

Shear = 4000 x 4.5 = 18000#

Average shearing stress = $\frac{18000}{20 \times 12}$ = 75# per sq. in

Shear carried by concrete = 30 x 20 x 12 = 7,200#

Shear to be carried by steel = 18,000 - 7,200 =

10,800#

Area of web reinforcement = $\frac{10,800}{12,000}$ = .90 sq. inch

CENTER COLUMN FOOTING.

Area of footing = $\frac{617,400}{4000}$ = 154 sq. ft. Use

12'6" x 12'6"

Moment at center = $\frac{4000 \times (6.25)^2 \times 12}{2}$ = 936000"#

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$$\frac{M}{bd^2} = 109 = \frac{936,000}{12 \times d^2}$$

$$d = \sqrt{\frac{936,000}{12 \times 109}} = 27" = 2'3"$$

Area of steel = .0107 x 27 x 12 = 3.47 sq. inches.

Shear = 4000 x 6.25 = 25,000#

Average shearing stress = $\frac{25,000}{27 \times 12}$ = 77#

Shear carried by concrete = 27 x 12 x 30 = 9,700

Shear to be carried by steel = 25,000 - 9,700 =

15,300#

Area of web reinforcement = $\frac{15300}{12,000}$ = 1.28 sq. in

CANTILEVER GIRDERS. (Section A.)
(See Drawing No. 15)

M = 309,300 x 3.5 x 12 = 12,970,000"#s

$$\frac{M}{bd^2} = 109 = \frac{12,970,000}{36 \times d^2}$$

$$d = \sqrt{\frac{12,970,000}{36 \times 109}} = 57.5"$$

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Wt. of lin. ft. of beam = $\frac{36 \times 57.5}{144} \times 150 = 2157\#$

P.L. Moment = 2157 x 4.5 x 1.75 x 12 = 203,300"#s

Total Moment = 12,970,000 + 203,300 = 13,173,300

$\frac{M}{bd^2} = 109 = \frac{13,173,300}{36 \times d^2}$

$d = \sqrt{\frac{13,173,300}{36 \times 109}} = 58.9"$

Area of steel = .0107 x 36 x 58.9 = 22.7 sq. in.

End Shear = $\frac{309,300 \times 26}{22.5} = 357,000\#$

Average Shearing stress = $\frac{357,000}{36 \times 58.9} = 169\#$ per sq. in.

Shear carried by concrete = 36 x 58.9 x 30 = 63,600#

Shear to be carried by steel = 357,000 - 63,600 =

293,400#

Area of steel = $\frac{293,400}{12,000} = 24.5$ sq. inches.

Area of stirrups 6" apart = $\frac{24.5}{6} = 4.1$ sq. in.

1¼" stirrup in double loop

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SIDE COLUMN CANTILEVER GIRDERS. (Section B.)

(See Drawing No. 16)

$M = 229,300 \times 3.17 \times 12 = 8,710,000$"#s

$$\frac{M}{bd^2} = 109 = \frac{8,710,000}{36 \times d^2}$$

$$d = \sqrt{\frac{8,710,000}{36 \times 109}} = 47" = 3'11"$$

Wt. of lin. ft. of beam $= \frac{36 \times 47}{144} \times 150 = 1760$#

P.L. Moment $= \frac{1760 \times (4)^2 \times 12}{2} = 169,000$"#s

Total Moment = 8,610,000 + 169,000 = 8,779,000"#s

$$\frac{M}{bd^2} = 109 = \frac{8,779,000}{36 \times d^2}$$

$$d = \sqrt{\frac{8,779,000}{36 \times 109}} = .48" = 4'0"$$

Area of steel = .0107 x 36 x 48 = 18.5 sq. inches.

End Shear = 229,300 + 1760 x 4 = 236300# per sq. in.

Average shearing stress $= \frac{236,300}{36 \times 48} = 137$#

Shear carried by concrete = 36 x 48 x 30 = 51,800#

Shear to be carried by steel = 236,300 - 51,800 = 184500#

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Area of steel = $\frac{184,500}{12,000}$ = 15.4 sq. inches.

Shear at end of long arm = $\frac{8,779,000}{12 \times 19.33}$ = 37,850#

Area of beam at average shearing stress of 100# =

$\frac{37850}{100}$ = 378.5 sq. inches.

Depth of beam = $\frac{378.5}{36}$ = 10.5" Use 12 "

Shear carried by concrete = 36 x 12 x 30 = 12,970#

Shear to be carried by steel = 37,850 - 12,970 =

24,880#

Area of steel = $\frac{24,880}{12000}$ = 2.08 sq. inches.

SIDE COLUMN FOOTINGS.

Area of footing = $\frac{229,300}{4000}$ = 57.3 sq. ft. Use 8'

x 8'

Moment at center = $\frac{4000 \times (4)^2 \times 12}{2}$ = 384,200"#s

$\frac{M}{bd^2}$ = 109 = $\frac{384,200}{12 \times d^2}$

d = $\sqrt{\frac{384,200}{12 \times 109}}$ = 18" = 1'6"

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Area of steel = .0107 x 18 x 12 = 2.31 sq. inches.

Shear = 4000 x 4 = 16,000

Average shearing stress $= \frac{16000}{18 \times 12}$ = 74# per sq. sq.in.

Shear carried by concrete = 30 x 18 x 12 = 6,480#

Shear to be carried by steel = 16,000 - 6,480 =9,520#

Area of web reinforcement $= \frac{9520}{12000}$ = .794 sq. in.

CENTER COLUMN FOOTINGS.

Area of footing $= \frac{457,500}{4000}$ = 114.2 sq. inches Use

11' x 11'

Moment at center $= \frac{4000 \times (5.5)^2 \times 12}{2}$ = 734000"#s

$\frac{M}{bd^2} = 109 = \frac{734,000}{12 \times d^2}$

$d = \sqrt{\frac{734,000}{12 \times 109}}$ = 24" = 2'0"

Area of steel = .0107 x 24 x 12 = 3.08 sq. inches.

Shear = 4,000 x 5.5 = 22,000#

Average shearing stress $= \frac{22,000}{24 \times 12}$ = 76.5# per sq. in

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Shear carried by concrete = 24 x 12 x 30 = 8,640#

Shear to be carried by steel = 22,000 - 8,640 = 13360#

Area of web reinforcement = $\frac{13,360}{12,000}$ = 1.11 sq. in.

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Section B.

CORNER COLUMN FOOTINGS.
(See Drawing No. 17)

Area of footing $= \frac{112,100}{4000} = 28.05$ sq. ft. Use 5.5' x 5.5'

Moment at center $= \frac{4000 \times (2.75)^2 \times 12}{2} = 182,000$"#s

$\frac{M}{bd^2} = 109 = \frac{182,000}{12 \times d^2}$

$d = \sqrt{\frac{182,000}{12 \times 109}} = 12"$

Area of steel = .0107 x 12 x 12 = 1.56 sq. in.

Shear = 4000 x 2.75 = 11,000#

Average shearing stress $= \frac{11000}{12 \times 12} = 76.5$# per sq. in

Shear carried by concrete = 12 x 12 x 30 = 4,300#

Shear to be carried by steel = 11000 - 4300 = 6,700#

Area of steel $= \frac{6,700}{12000} = .56$ sq. in.

CORNER COLUMN CANTILEVER GIRDERS.

M = 112,100 x 4.62 x 12 = 6,220,000"#s

$\frac{M}{bd^2} = 109 = \frac{6,220,000}{36 \times d^2}$

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$$d = \sqrt{\frac{6,220,000}{36 \times 109}} = 40" = 3'4"$$

Wt of lin. ft. of beam $= \frac{36 \times 40}{144} \times 150 = 1500\#$

P.L. Moment $= \frac{1500 \times (4,62)^2 \times 12}{2} = 192,500"\#s$

Total Moment = 6,220,000 + 192,500 = 6,412,500"#s

$$\frac{M}{bd^2} = 109 = \frac{6,412,500}{36 \times d^2}$$

$$d = \sqrt{\frac{6,412,500}{36 \times 109}} = 41" = 3'5"$$

Area of steel = .0107 x 36 x 41 = 15.8

End Shear = 112,100 + 1500 x 5.5 = 126,350#

Average shearing stress $= \frac{120,850}{36 \times 41} = 81.6\#$ per sq. in

Shear carried by concrete = 36 x 41 x 30 = 44,250#

Shear to be carried by steel = 120,350 - 44,250 =

76,100

Area of steel $= \frac{76,100}{12000} = 6.35$ sq. inches.

Shear at end of long arm $= \frac{6,412,500}{22.38 \times 12} = 24,000\#$

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Area of beam shearing stress 100# = $\frac{24,000}{100}$ = 240 sq in.

Depth of beam = $\frac{240}{36}$ = 7" Use 12"

Shear carried by concrete = 36 x 12 x 30 = 12,970

Shear to be carried by steel = 24,000 x 13,000 = 11000

Area of steel = $\frac{11,000}{12,000}$ = .92 sq. inches.

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Section E.

CENTER COLUMN FOOTINGS.
(See Drawing No. 19)

Area of footing = $\frac{322,000}{4,000}$ = 80.5 sq. ft. Use 9' x9'

Moment at center = $\frac{4000 \times (4.5)^2 \times 12}{2}$ = 492000"#s

$\frac{M}{bd^2}$ = 109 = $\frac{492,000}{12 \times d^2}$

d = $\sqrt{\frac{492,000}{12 \times 109}}$ = 20"

Area of steel = .0107 x 12 x 20 = 2.57 sq. inches.

Shear = 4000 x 4.5 = 18,000#

Average shearing stress = $\frac{18000}{12 \times 20}$ 75# per sq. in.

Shear carried by concrete = 12 x 20 x 30 = 7,200#

Shear tp be carried by steel = 18000 - 7,200 = 10,800#

Area of steel = $\frac{10,800}{12,000}$ = .90 sq. inches.

COLUMNS BETWEEN SECTIONS A & E

Area of footing = $\frac{504,300}{4000}$ = 126 sq. ft. Use 12' x 12'

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Moment at center = $\frac{4000 \times (6)^2 \times 12}{2}$ = 864,000"#s

$\frac{M}{bd^2} = 109 = \frac{864,000}{12 \times d^2}$

$d = \sqrt{\frac{864,000}{12 \times 109}} = 26"$

Area of steel = .0107 x 12 x 26 = 3.34 sq. inches.

Shear = 4000 x 6 = 24,000#

Average shearing stress = $\frac{24000}{12 \times 26}$ = 77# per sq. in.

Shear carried by concrete = 12 x 26 x 30 = 9,350#

Shear to be carried by steel = 24,000 - 9,350 = 14650

Area of steel = $\frac{14650}{12000}$ = 1.22 sq. inches.

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